Integrated Testing of Launch Vehicle Telemetry Avionics Using PXI and NI LabVIEW

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Abstract

The miniaturization of avionics has placed more and more functionality into a single package making its test system more complex. The increased complexity of such a test system is managed here by an ATE with a PXI system as its hardware platform and National Instruments' graphical programming environment of LabVIEW as the software platform. The additional time to test this increased package complexity is tackled by providing greater parallelism in test while significantly decreasing the throughput overhead of the test system architecture. This paper presents the system configuration and implementation details of an efficient, cost effective and faster virtual instrumentation based automated checkout for the test and evaluation of Advanced Telemetry System proposed for the present and future launch vehicles of India. The test system developed in-house has considerably reduced the Test & Evaluation time and can be used by a person with less expertise to test the complex telemetry avionics. Further the system is highly modular in nature, offers high portability and is more compact, versatile and easier to setup and use. The modular architecture makes it easy to insert new product and technology to extend the effective life of the test system.

Introduction

The advancements in electronic circuit design have resulted in miniaturization, field programmability, adaptability etc in almost every field of its application. ISRO also moved along with the advancements in electronic circuit design and packaging resulting in the design of new generation launch vehicle avionics called Advanced Mission Computer systems (AMC) and Advanced Telemetry Systems (ATS). This has brought out weight reduction in avionic systems and subsequent enhancement in the launch vehicle payload capability. When this was proposed, testing of these avionics with new generation ATE was also thought of. Towards this the pros and cons of different test system architectures were considered and finally we arrived at a configuration based on PXI/cPCI [2]. Also before deciding this platform for our test system development we have made a comparative study on the traditional industrial PC based system and the new generation PXI system for selecting the better option in terms of technology, cost effectiveness, compactness and portability. The availability of all required equipments and interface modules in PXI/cPCI was one of the major considerations to extract the best benefit out of the new platform. The process of making custom circuits required for the checkout hardware in PXI prototyping boards or using the new generation Re-configurable I/O modules based on FPGA is under progress.

The heart of any Launch Vehicle Telemetry System is the Pulse Code Modulator and Controller, which formats the data from different remote measuring units, does coding and controls different measuring units placed at remote locations depending upon the telemetry requirements of a particular mission. The telemetry system also include data storage portion for storing the telemetry data during RF non-visibility with the ground stations and re-transmitting it after gaining visibility to avoid any data loss. The 1553B bus-monitoring portion is also a part of the new telemetry system for recording the communication and reporting error, if any, in the Navigation, Guidance and Control communication link of the launch vehicle. These three functionalities have been realized in a single package called Integrated Control Unit (ICU). This has necessitated the simultaneous testing of these three functionalities using a single ATE with multi-port architecture. Some of the Remote Units (RU) are also stacked with ICU for integration easiness. This necessitates the testing of these RUs along with ICU especially during environmental tests like thermal, vibration, shock etc.

The graphical programming environment of National Instruments' LabVIEW is well known for its intuitive and user-friendly features. The experiences we had with LabVIEW in automatic test system development have prompted us to favor LabVIEW 7 Express for checkout software development.

System configuration & implementation

System Requirements

The major requirements of the test system include periodic monitoring of the power input, the final output and the checkout port output of the Unit Under Test (UUT), analyze the data and update the display in near real-time, generating different pulsed commands to select the different modes of operation of the UUT, testing the various functionality of the UUT in simultaneous and continuous mode with different inputs like LSB data, MSB data, counter data, 1553 bus communication with valid and error data and AC & DC signals of varying amplitude and frequency, generating the test report and error reports, storing the data etc. All these requirements were fully met with the PXI based checkout developed.

Hardware implementation: The checkout hardware was configured by using a PXI chassis and a controller from National Instruments with PXI/cPCI instrument modules from different vendors. The different modules used are listed below with the name of the manufacturer.

1. Power supply Module	M/s Chroma ATE INC
2. Oscilloscope module	M/s National instruments.
3. PCM data acquisition module	M/s Lumistar LLC.
4. 1553 B communication module	M/s Excalibur Systems.
5. High count Mux module	M/s Pickering Interfaces Ltd.
6. Switch module	M/s National instruments.
7. Function Generator module	M/s National instruments.
8. RU simulator module	In-house made
9. CCU simulator module	In-house made
10. OBC serial link simulator	In-house made

The PCM data acquisition module supports data rate up to 20 Mega bits per second as against our requirement of 2 Mbps. The 1553 B communication module supports the Remote Terminal (RT), Bus Controller (BC) & Bus Monitor (BM) modes of operation of 1553 B MIL-STD bus. The high-count multiplexer module, which is having 198 SPST switches, is used to give input to 128 analog and 20 digital channels of Remote Units (RU). The versatility of the PXI architecture and its compatibility with cPCI modules are evident from this multi-vendor support for the different instrument modules. The block schematic of the ATE is shown in Figure.1.

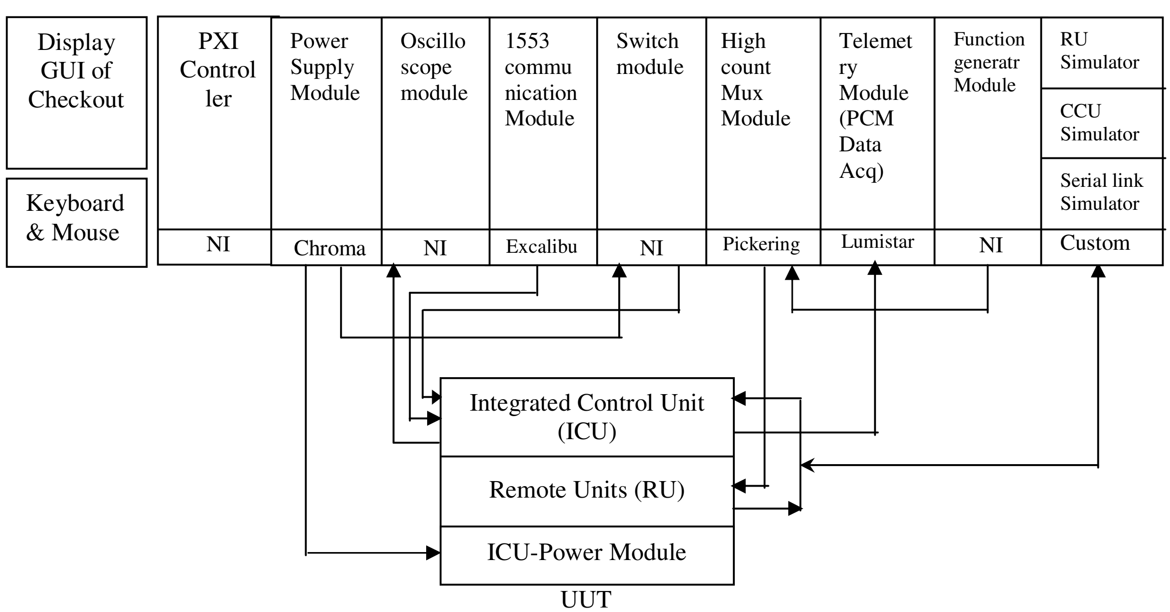
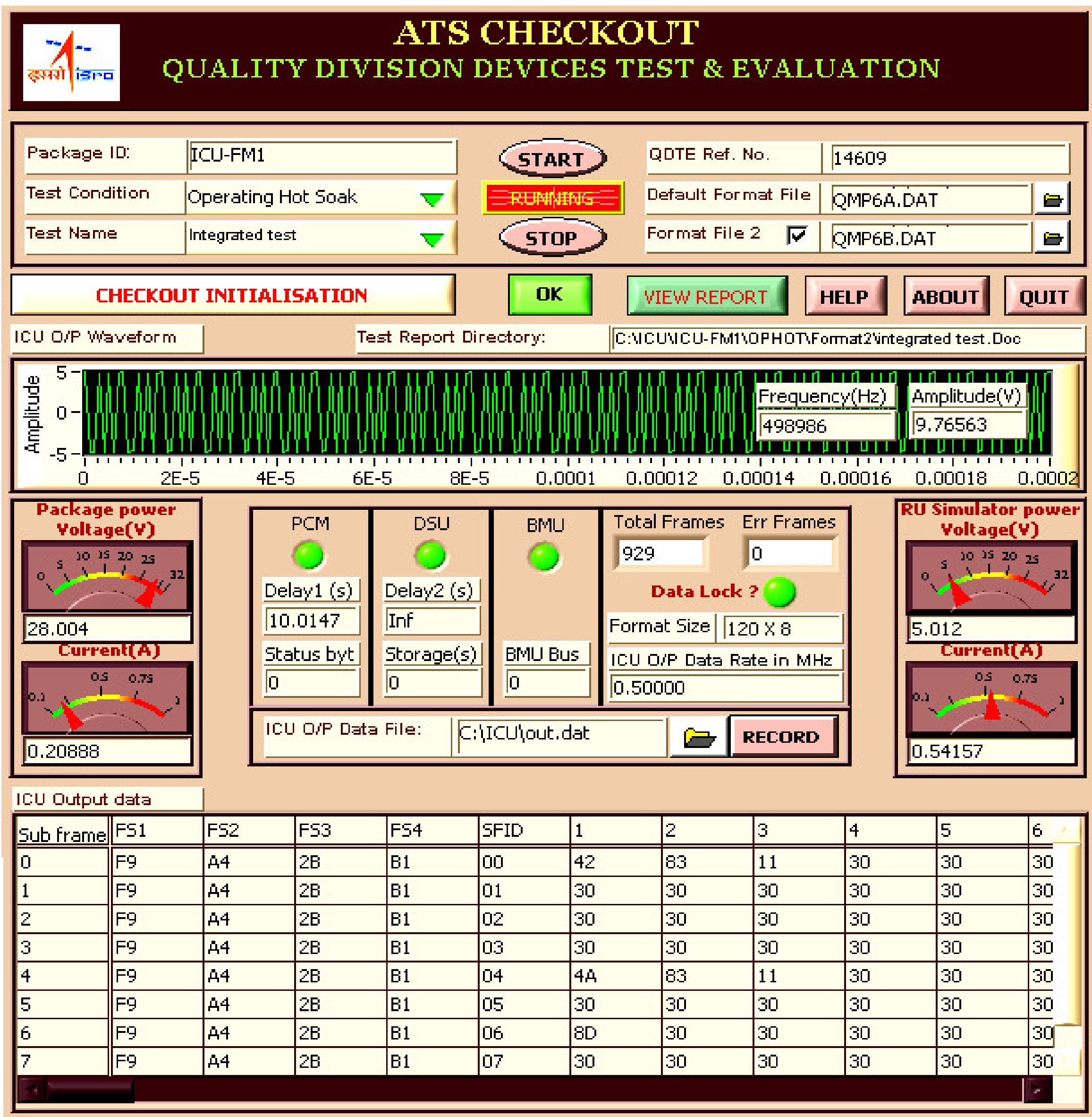


Figure 1. Block schematic of Advanced Telemetry System (ATS) checkout

Software implementation: The software was developed using the graphical programming environment of LabVIEW 7 Express. Greater parallelism implemented using the multithreading architecture of LabVIEW has helped the simultaneous testing of all the three major functionalities of the UUT. The checkout software is highly modular and gives room for easy expansion. The modular architecture of the checkout allows easy expansion for making it a universal checkout system for testing other avionic packages in the telemetry chain.

The inherently easy-to-use nature of Express VIs in LabVIEW 7 Express has greatly helped in the software development. Also the Express VIs due to their interactive, configuration-based interface have helped in understanding, debugging and modifying the code during the development phase much easier. This we hope will make the maintenance of the system much simpler and transferable. Also the built-in measurement capabilities of LabVIEW has helped a lot in the development phase.

GUI of the checkout: The Graphical User Interface (GUI) (shown in figure 2) of the checkout allows the user to do the checkout intialisation, to select different tests like Bit rate accuracy, Bit rate stability, MSB & LSB data verification, Delayed data verification, Stored data verification, Various command interface logic tests, 1553B communication with valid and error commands, Power supply variation test, RU test etc. Also the test results are updated in the GUI in real time.



Sub frame	FS1	FS2	FS3	FS4	SFID	1	2	3	4	5	6
0	F9	A4	2B	B1	00	42	83	11	30	30	30
1	F9	A4	2B	B1	01	30	30	30	30	30	30
2	F9	A4	2B	B1	02	30	30	30	30	30	30
3	F9	A4	2B	B1	03	30	30	30	30	30	30
4	F9	A4	2B	B1	04	4A	83	11	30	30	30
5	F9	A4	2B	B1	05	30	30	30	30	30	30
6	F9	A4	2B	B1	06	8D	30	30	30	30	30
7	F9	A4	2B	B1	07	30	30	30	30	30	30

Figure 2. Graphical User Interface of Advanced Telemetry System (ATS) Checkout

During the initialization phase the checkout will initialize all instrument modules and check its proper functionality. Once the checkout initialization is completed without any error, the checkout status window will show 'Ready to start test' status. The user can now select different test conditions viz. Initial Standard Room Condition (ISRC), Hot soak, cold soak, vibration-lateral, vibration-thrust, Shock, EMI etc and also different tests from the pull-down menu in the GUI and start the test. The selected test will keep on running in a continuous mode till the user stops it. During each test the number of frames tested and number of errors occurred along with the raw output data from the package will be updated in the display of the GUI in real-time. Also during the test the user can store the raw data in the hard disc of the system for a specified duration in a specified location given by the user by pressing the 'Record' button in the GUI. The errors in each functionality of the package will be indicated by the corresponding LED in the GUI during different tests. The telemetry data lock (with the frame sync pattern, sub frame ID and frame size) status will also be displayed in real-time. The Oscilloscope module in the ATE monitors the final output signal from the UUT and measures its amplitude and frequency and deviation if any will be prompted to the user while other tests are going on.

Just after stopping any test, a consolidated report containing information on the total number of frames compared, total error frames with errors and deviations and the values of measured parameters like accuracy, delay duration, storage duration, re-transmission rate etc will be generated in MS Word format and stored in a directory structure automatically generated from the Package ID, Test condition and test name information. These consolidated reports are used at the end of test & evaluation phase for generating the final detailed test report of the system in a pre-defined format based on ISO 9000 requirements. The checkout also provides a help file with the details of the UUT, different tests, precautions to be taken during testing etc. The checkout is having an auto mode of operation by which the entire tests in a test condition will be executed in a sequential mode and finally a report will be generated. By this the manual intervention is greatly reduced.

System Performance & benefits

The performance of an automatic test system is always linked to the performance of the instrument interface architecture used in the system. The PXI is one such instrument interface standard that offers many benefit for test and measurement automation applications. The PXI modular instrumentation leverages the high speed PCI bus, which is the de facto interface standard for plug-in boards of computers. Here in this system the incorporation of PXI instrumentation has resulted in advantages like high system throughput, system ruggedness, modularity, compactness and portability.

The system benefits can be summarized below:-

1. A reduction of approximately 60% in overall system size compared to industrial PC based setup, resulting in a highly compact and portable system. This was mainly due to the incorporation of PXI instrumentation.

2. A savings of approximately 25% in initial overall system cost. This was mainly due to the high switching requirements of the system. The savings will be much higher when the overall lifetime cost and short system development time is considered.

3. Superior system throughput by using PXI instruments instead of instruments with traditional interfaces like GPIB. This for example has helped to monitor the variations in power input to UUT in a more frequent interval of 100 ms to avoid the possibility of over voltage or current to the UUT for a longer duration.

4. The integrated testing due to the parallelism provided in the software has helped to test the full functionality of the UUT simultaneously in a continuous mode in short duration environmental tests like vibration, shock etc.

5. Short system development time resulting in immediate introduction to application.

6. The modular architecture of the checkout allows easy expansion with minimal hardware and software modifications for making it a universal checkout system for testing other avionic packages in the telemetry chain. The modular architecture also makes it easy to insert new product and technology to extend the effective life of the test system.

Conclusion

Here a modular ATE development using PXI and NI LabVIEW is discussed along with its advantages over traditional ATE. For general purpose and base band frequencies as well as control and monitoring applications, PXI will be a better choice. Also wherever high switching requirement is there PXI based system will be the cost effective solution. The modular architecture of the PXI based ATE delivers rapid test system development and long term scalability. The portability and compactness are the other considerations, which favors PXI solution. Based on our experiences and study it can be concluded that depending on the specific instrumentation and switch module requirements, a PXI system will prove to be the better choice in terms of technology, cost effectiveness, compactness and portability. This developmental study has also paved way for establishing a new standard in ATE development for avionics packages in our centre.

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